PERGAMON

Neuropsychologia 37 (1999) 1041–1047

NEUROPSYCHOLOGIA

Hemispheric dominance and gender in the perception of an illusion

Shardad Rasmjou*, Markus Hausmann, Onur Güntürkün

Biopsychologie, Fakultät für Psychologie, Ruhr-Universität, 44780 Bochum, Germany

Received 24 June 1998; accepted 10 November 1998

Abstract

Perception of geometric illusions is a visuo-spatial process. As such processes often have been found to be predominantly the domain of the right hemisphere, this hemisphere may be expected to perceive such illusions more readilly than the left hemisphere. Using the herringbone illusion in a reaction-test paradigm, we found that in right-handed males the right hemisphere was significantly more often deceived than the left, whereas no significant hemispheric difference was observed in females. This is the first demonstration of gender differences in the lateralized perception of an illusion.

Keywords: Hemispheric dominance; Lateralization; Illusion; Gender; Reaction test

1. Introduction

1.1. Categories of illusion

Optical (or geometrical) illusions may possibly be the unplanned side effects of mechanisms which have evolved to fine-tune a specie's perceptual and cognitive capabilities [11], and may thus involve psychological top-down projection of patterns, knowledge, and asumptions onto assumed reality. Gregory [13] has differentiated between illusions as: 'ambiguities, paradoxes, fictions, and distortions'.

'Ambiguities' are illusions, such as the Necker cube, which can assume different spatial configurations; 'paradoxes' are those such as the impossible Penrose triangle; 'fictions' are the likes of the Kanizsa triangle, where merely the presence of 'pacmen' at the corners induce the imagination of illusory contours making up the sides; and 'distortions', or more accurately 'perspective distortions', are those with which we shall here be dealing with. Some well-known examples of perspective distortions are the Ponzo illusion, where two short paralell lines of identical length appear to differ in length when placed between oblique lines that resemble receding railway lines; the Zöllner illusion, where several perfectly paralell lines appear no longer to be paralell when crossed by many small oblique hatchings; the Müller–Lyer illusion, where two equal lines appear unequal if one bears outward-pointing arrows at both ends, whereas the other line bears inward-pointing arrows at both ends; and the Poggendorff illusion, where the two ends of a perfectly straight but oblique line, interrupted in the middle by two paralell lines (as though edges of a superimposing object) appear no longer continuous but laterally displaced, although this latter illusion may be a combination of both 'fiction' and 'distortion'.

1.2. Illusions and laterality

As with many cerebral activities, the perception of illusions also appears to be lateralized, that is, many illusions have been found to deceive the left and the right hemispheres to different degrees. However,

* Corresponding author. Tel.: +49 234 700 5485; fax: +49 234 7094 270.

E-mail address: shardad.rasmjou@ruhr-uni-bochum.de (S. Rasmjou)

0028-3932/99/$ - see front matter
PII: S0028-3932(98)00154-7

although the majority of such studies have indicated the right hemisphere more prone to be deceived than the left, there appears to be no concensus in the literature. Holmes ([20], quoted by Greist and Grier [14]), using the Müller–Lyer distortion illusion, apparently found no hemispheric dominance. Clem and Pollack [8] on the other hand, using the same illusion did find right hemispheric dominance. However, in efforts to investigate the development of the susceptibility to illusions with increasing age, they dissociated the illusion into two parts: the straight lines and the terminal distortion-inducing arrows. When they presented these two components in succession (also tachistoscopically but with an ISI of 500 ms), they found the opposite hemispheric dominance. Greist and Grier (using the Poggendorff distortion illusion [14]), and Bertelson and Morais (using a variation of the Ponzo distortion illusion [3]) also found no hemispheric dominance. Rothwell and Zaidel [47], used the Oppel–Kundt distortion (an illusion where the extent of a figure is overestimated when filled with shading lines, compared to the same figure when empty), and did find right hemispheric dominance. However, they found no dominance when they presented the two figures that were to be compared in succession, with an ISI of 2 s.

Several clinical studies of patients with damage to only one hemisphere have provided further evidence. Houlard et al. [22] employed the Müller–Lyer and the Ponzo distortions, and found that patients with left-hemisphere lesions perceived the illusions well, whereas in those with right-hemisphere lesions the perception was weakened. Grabowska et al. [12] employed the Ponzo, the Poggendorff, the Zöllner, and the Ehrenstein–Orbison illusions (the latter also a distortion illusion), with right and left brain-damaged subjects, but the comparison of their performances did not reveal any conclusive differences.

1.3. Gender and laterality

Another aspect of hemispheric specialisation, and cognition overall, are gender differences. Although performances of both genders overlap to a large degree [35], women are found to outperform men in many aspects of verbal ability [15, 33], while men tend to outperform women in spatial tasks [15,23,30,53,55]. Cerebral asymmetries of speech [6,17,50], and spatial orientation [7,9,54] are also known to be gender dependent. All in all, with the exception of a few contrary findings [1,4,28], the majority of studies, including also clinical investigations, demonstrate that the lateralization of these processes is more pronounced in males, while females exhibit more symmetrical functional cerebral organisation [9,15–17,21,25,26,31–34,50].

1.4. Illusions and gender

During adolescence, females and males undergo diverging patterns of cognitive development [56]. Since the divergence in development apparently also includes susceptibility to illusions [45], it has been thought that perhaps the differences in susceptibility in males and females may well survive into adulthood. However, an extensive study by Porac et al. [42], using 107 females and 114 males (employing 12 of the most common illusions and 11 variations of the Müller–Lyer) failed to reveal any differences. Also Beckett [2], using the Poggendorfff illusion, and Holland et al. [19] using the Baldwin illusion (an illusion of line-length distortion similar to the Müller–Lyer), reported having observed no differences. Pratarelli and Steitz [44] on the other hand, using what they call spatial illusions, did find that males were about 4 times faster than females in recognizing hidden forms against complex backgrounds. However, one may arguably consider these not as tests of susceptibility to illusions, but rather of general cognitive ability. We point out here, that in all the studies of the gender factor in the perception of illusions mentioned here, lateralized perception had not been the issue, and the subjects had viewed the stimuli only foveally.

1.5. Illusions, gender and laterality

Thus far, there has been no study showing the simultaneous interaction of all three variables, namely *gender differences* in the *lateralised perception* of *illusions*. We thus studied both aspects of this issue in the perception of the herringbone illusion. As we shall further expound in the discussion, many illusions often investigated, such as the Ponzo, the Müller–Layer and the Poggendorff, are not robust enough when laterally viewed [3,41]. Most of these illusions are based on the perception of imaginary contours, an ability which apparently decreases with lateral viewing [18]. The herringbone illusion (Fig. 1, stimuli 7–8), in which a vertical herringbone shading inside a square distorts (slants) the sides, giving the impression of a trapeze, does not depend on the perception of imaginary contours and is thus robust enough for lateral viewing.

2. Materials and methods

2.1. The stimuli

There are four different methods of tachistoscopic presentation of stimuli: threshold detection, stimulus identification, immediate stimulus matching, and delayed stimulus matching [49]. In this study we used a combination of two of these, namely identification and immediate matching. The task was to identify and report, while fixating a small central cross, which of the two simultaneously appearing figures on the left and right of the fixation cross was a trapezoid.

There were four different stimuli, consisting of variations of two shapes: a square and a trapeze, each with either of two different shadings: simple diagonal or herringbone. Eight pairs of different combinations of these four, with a fixation cross in between (shown in Fig. 1), were tachistoscopically presented on a monitor, of which only stimuli 7–8 bore the illusion. We shall later refer to these as the 'critical' trials, for the analysis of the results will be based mainly on the responses to these. The other six pairs were presented to camouflage the experimental intentions, as well as to control the subject's ability to identify a true trapezoid.

At a distance of 50 cm from the monitor, the distance from the central cross to the nearest edge of either figure on the right and left subtended 4.0°. The height and width of the square, and the lower edge of the trapeze measured 7.4°; the upper edge of the trapeze measured 6.8° and thus although readily recognizable as a trapeze, it only slightly ($7.4-6.8° = 0.6°$) deviated from a square at its upper edge. The figures were white lines on a black background, at an intensity such that after screen blanking any persisting phosphorescence was not noticable in the darkened room. The stimuli were presented such that, every 4 s, the central cross appeared first, followed 0.5 s later by a stimulus pair, 180 ms after which the screen was blanked. The eight combinations were presented 80 times pseudo-randomly (lasting 5 min), followed by a posture and eyes rest of approximately 20 s. Five such sessions were administered consecutively (lasting a total of 30 min), at the end of which the subject had been exposed 400 times to the stimuli (50 exposures to each of the eight pairs).

The experimental setup consisted of a personal computer (Compaq Deskpro 286), the paralell port of which was connected to two microswitches operated by the subjects. The computer hosted two graphic controllers, one generating the stimuli on the monitor in the experimental room, the other displaying the experimental progress on a second monitor observable only to the experimenter in another room. The stimuli were generated by a program written by the authors in 'C'. Within a temporal window of 2 s after the presentation of each stimulus, the program monitored the state of the paralell port (hence that of the two microswitches), grouping and recording the L/R responses made to each stimulus pair.

2.2. Subjects

The subjects consisted of 20 males (age range: 17–57, mean: 30.1 ± 10.71), and 21 females (not in their menstrual phase, age range: 19–45, mean: 25.71 ± 7.5), who were mostly university students.

They were all dextral, according to the Edinburgh Handedness Inventory [5,39], and were screened for corneal irregularities (astigmatism) by having them monocularly fixate 5° to either side of a perfectly vertical line. They were excluded from the study if they reported seeing perceptible deviations from absolute verticality in either eye, an important screening feature of this study, for we have observed (unpublished), that such defects can distort the fine geometries of laterally presented stimuli per se.

2.3. Experimental protocol

The subjects sat, their arms resting on the table in front of them, while their heads were imobilized by a chin and forehead rest placed 50 cm from the monitor. To reduce undue fatigue and the ensuing lack of concentration, chair and chin-rest height were individually adjustable. Each hand rested on a microswitch of its own, separated laterally by 25 cm, thus spatially corresponding with the separation of the two figures on the screen.

In lieu of an explanation they were shown only stimulus 4 (Fig. 1) and given the following instructions: (1) to fixate the central cross as soon as it appeared; (2) if a trapezoid was identified, to press the switch on the side that it appeared with the corresponding hand, as quickly as possible and without much contemplation (but within 2 s); (3) a trapeze was to be identified not from its inner shading (which was subject to change), and not by judging simply from the slant of the edge nearest to the fixation cross, but from its overall impression; (4) That although the figure on the right of the demonstration stimulus (Fig. 1, stimulus 4) was clearly a trapeze, successive trapezoids would at random have their sides so minutely slanted, that although still a trapeze, the difference to a square would be very hard to determine. This was misinformation, but it primed the naive subject for the herringbone square when it appeared. It also effectively disarmed those who may have been acquainted with the illusion, since they could no longer be certain whether it was the illusion (in reality a square), or a figure still geometrically definable as a trapeze; (5) that the choice would be go/no-go; 'go', if the trapeze appeared on one side only, and 'no-go', if both sides appeared trapezoidal.

3. Results

Table 1 summarizes the grouped means and standard deviations of the total responses of all 41 subjects

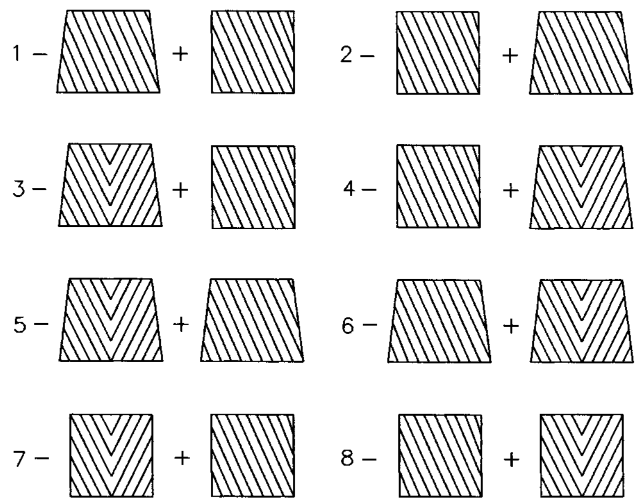

Fig. 1. Stimuli pairs used in the experiment, each pair with a fixation cross in between. Figures are either a square or a trapeze, each with one of two different shadings: diagonally-hatched or herringbone. Pairs 1–6 serve as control stimuli and to mask the experimental intentions; only pairs 7–8 bear the herringbone illusion, i.e. stimulus 7-left and stimulus 8-right. Here, the herringbone shading inside the square induces perceptual slanting of the sides, creating the illusion of a trapeze. The stimuli are arranged so that the trapezoids appear grouped in columns, facilitating the comparison and the observation of the trend in the responses made to them (Table 1).

Table 1
Responses of all 41 subjects to the stimuli pairs shown in Fig. 1, the numbers in brackets corresponding to the same numbers for the stimuli. Below each stimulus number is the corresponding grouped mean ($N = 50$) and S.D. of responses for the subjects; male (M, upper rows), female (F, lower rows), where the responses to the preferred visual field is printed in bold letters. The number of L/R responses to each stimulus pair does not always add up to $N = 50$, especially for stimuli 5–8, since subjects did not respond when uncertain, or when they perceived both figures as identical

	L	R	L	R
	(1)		(2)	
M	**41.5** ± 11.0	0.4 ± 0.7	1.0 ± 2.1	**39.4** ± 12.6
F	**42.5** ± 4.8	1.3 ± 2.2	3.3 ± 4.6	**41.8** ± 6.5
	(3)		(4)	
M	**49.2** ± 1.8	0.2 ± 0.9	0.2 ± 0.5	**47.5** ± 5.3
F	**49.3** ± 0.9	0.3 ± 0.8	1.3 ± 1.6	**48.4** ± 1.8
	(5)		(6)	
M	**40.0** ± 8.9	3.9 ± 5.2	7.8 ± 7.1	**31.5** ± 12.5
F	**34.0** ± 13.0	8.0 ± 9.0	10.3 ± 8.6	**34.7** ± 10.7
	(7)		(8)	
M	**35.2** ± 11.3	1.3 ± 3.5	2.5 ± 4.0	**24.9** ± 14.4
F	**33.9** ± 11.4	4.8 ± 5.9	5.5 ± 6.4	**32.7** ± 11.8

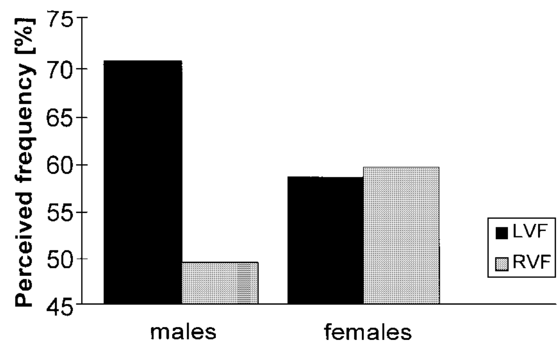

Fig. 2. Frequency of response of the subjects to the laterally-presented illusory trapeze (Fig. 1, stimulus 7-left, stimulus 8-right). Whereas significant left visual field perception is observed for the male sample group (right hemipheric perception), the female group exhibits almost no asymmetrical perception.

to the eight pairs of stimuli shown in Fig. 1. As a control, the responses made to stimuli 1–4 illustrate that in every pair both genders have been able to perceive and identify a true trapeze with 80–100% accuracy. The responses of main interest are those made to stimuli 7–8, which bear the illusion. These were analyzed with repeated-measures ANOVA (right visual field vs left visual field), with gender as the between-subject variable. As with the perception of the true (control) trapezes, also the frequency of perception of the illusion was quite high (about 60%), and without any significant difference between the genders [$F(1,39) = 0.02$, n.s.]. Further, the ANOVA confirmed that visual field indeed was a significant source of variance [$F(1,39) = 6.16$, $P < 0.05$], supporting a left visual field advantage (right hemisphere) for perceiving the illusion. It also yielded significant interaction between the two factors, visual field and gender [$F(1,39) = 7.51$, $P < 0.01$]. These results are graphically shown in Fig. 2, where visual-field differences in females appears negligible, whereas for males the left visual-field superiority is significant, attesting to right hemispheric dominance. The posthoc test (Scheffé) also yielded high significance [$P = 0.0089$] for right hemispheric asymmetry in males, but no significant asymmetry [$P = 0.9983$] for females.

Also striking appear to be the responses made to stimuli pairs 5–6. Here, both genders have responded more often to the 'enhanced' trapeze (with herringbone shading), whereby males have responded more often when it appeared in the left visual field. In these stimuli both figures are trapezoid, and the subjects had been given instructions not to respond in such cases. We conjecture, that the herringbone shading may so much enhance the trapezoid impression, that the figure on the other side may *by comparison* appear as a square. Also here the ANOVA showed no significant [$F(1,39) = 0.85$, n.s.] gender differences in being deceived by the enhanced trapeze. However it did reveal visual field to be a marginally significant [$F(1,39) = 3.15$, $P < 0.10$, n.s.] source of variance, and the interaction between visual field and gender to be also of marginal significance [$F(1,39) = 3.63$, $P < 0.10$].

4. Discussion

This is the first demonstration of gender differences in the lateralized perception of an illusion, and the results in right-handed males demonstrate significant dominance of the right hemisphere in perceiving the herringbone illusion. Additionally, they show interaction between visual field and gender, i.e., for the critical trials, we find a cerebrally symmetrical perception of the illusion in females, in agreement with the generally more symmetrical organization often found in females [9,15–17,21,24–26,31,33,43,50]. A further finding here was that, irrespective of visual field, the illusion appeared to deceive both genders to equal extent, corroborating those studies which found no gender differences when subjects viewed illusions foveally [2,19,42,44].

As mentioned in the introduction, the contradictory findings of Clem and Pollack [8], and Rothwell and Zaidel [47], occurred only when they presented the dissociated components of an illusion successively, a condition which may, we surmise, lead to its perceptual break-down, since adequate interaction between the substrate and the inducing components may be limited to a very narrow temporal span. In support of this contention, recently Usher and Donnelly [52] have provided evidence that 'visual grouping' is facilitated when elements of a percept are presented at the same time as each other (within the integration time of the visual system), and can be divorced from the perception of other features by enforced temporal separation.

Greist and Grier [14] found no hemispheric dominance, but not only did they dismiss handedness in the choice of their subjects, but pooled the results of the mere four males and four females whom they tested. Exactly the same two shortcomings appear to plague the findings of Bertelson and Morais [3], who also found no hemispheric dominance. In clinical studies, Grabowska et al. [12] found no hemispheric dominance in brain-damaged patients, in whom they described the pathology as: "The lesions were mainly cortical, involving sometimes a portion of subcortical structures". Perhaps pertinent here are recent PET localization of areas responsible for visuospatial attention, revealing these to be deeper structures, mainly in the right hemisphere [38]. The lesions affecting the subjects in this study were not only too diffuse, but often too superficial.

As already mentioned, the choice of the stimulus may have been a critical factor in the outcome of the results. In planning these experiments, we had noticed (unpublished observations), that many 'fictitious' illusions, i.e., those involving the perception of imaginary contours such as the Poggendorff, Müller–Lyer or the Ponzo, were not robust enough for lateral viewing. Also Polich [41] reported that performance decreased with increasing angular presentation of the stimulus away from the fixation point. Bertelson and Morais [3] also made similar observations, although they attributed this to the brevity of the tachistoscopic presentation. Pertinent to these observations are recent findings by Hess and Dakin [18], who measured susceptibility to imaginary contours and found it to be reduced with increasing angular displacement from the fixation point, becoming totally absent in peripheral vision. If this susceptibility is responsible for the perception of the 'fictitious' illusions mentioned, it could account for the negative findings in the studies we have mentioned [3,8,14,47]. The herringbone illusion, on the other hand, is compelling even when viewed peripherally, as it does not involve the perception of imaginary contours.

Instrumental to these results may have been yet another aspect of the experimental paradigm, i.e., the type of response requested from the subjects. Perhaps the specification that response speed—although limited to a maximum of 2 s—was not as important as accuracy of the response, was a decisive factor here. This is in contradiction to the findings of Rothwell and Zaidel [47], who found the right hemisphere to be more susceptible to the illusion only when subjects had to respond quickly. However, they noted that their findings perhaps applied merely to the illusion they studied and not to illusions in general.

Also of importance in the experimental paradigm is the issue of unilateral vs bilateral presentation. In initial trials we employed unilateral presentation, which yielded basically similar results to those we have here presented. However, we finally chose bilateral presentation for the following reason. Although in the perception of a stimulus of interest presented laterally, another stimulus contralaterally presented may be redundant, this 'redundant-target' effect may apparently accelerate the cognitive process, yielding shorter reaction times [29,36,37,46]. Although we did not measure reaction times, we reasoned that the shorter responses may be due to reduced inter-hemispheric enquiry, since both hemispheres may be simultaneously occupied, each with a spatio-visual task of its own.

Furthermore to the choice of the stimulus, also the possible *combinations* of stimuli used may have been critical. In stimuli 7–8, had we paired the illusory figure with a true trapeze rather than with a square, the illusion would probably seldom have been perceived. This assumption is supported by considering the responses made to stimuli 5–6, where one stimulus appears to have been perceived, as we previously hinted, as relatively 'more' of a trapeze than the other. In these stimuli, the herringbone shading may be intensifying the trapeze form, for it is obviously the presence of these multiple 'V' forms that induces the illusory slanting of the sides of a true square (stimulus 7-left; stimulus 8-right). Comparison of responses made to stimulus 2-right with those made to stimulus 4-right would confirm that multiple 'V' forms and slanting sides do make a greater impression than slanting sides alone. Similarly, the multiple 'V' forms and the slanting sides of stimulus 5-left may make a greater impression than the slanting sides alone of the other figure. Since subjects were required to respond only to a trapeze, their anticipatory attention was focused on a stereotyped trapeze from memory. Thus the perception of the more salient trapeze, together with the brevity of the tachistoscopic presentation may have obliterated any memory of the other figure, a memory which would have been needed in the post-stimulus comparison period before a decision was reached. Thus the condition may well have simulated one of metacontrast masking (for a review see [10]).

Certainly, the more frequent identification of stimulus 5-left as a trapeze than 5-right, is an illusion in its own right, and the responses of the males further strengthen our findings for stimuli 7–8, that the right hemisphere is more readily deceived. Perhaps the greater susceptibility of this hemisphere to distortion illusions of this kind is the by-product of its finer discrimination of line orientations. In investigating male hemispheric asymmetry in the discrimination of line orientation, Kimura [27], Umilta et al. [51], Phippard [40], and Sasanuma and Kobayashi [48], all consistently found significant right hemispheric advantage. If we are correct in describing the herringbone illusion as a distortion of line orientation, comparison of the present findings with those of the latter studies would lead us to suspect that both effects are subserved by similar if not identical neural mechanisms.

Acknowledgements

We herewith thank the two anonymous reviewers whose valuable suggestions much improved this paper. Supported by the Deutsche Forschungsgemeinschaft.

References

[1] Ashton R, McFarland K. A simple dual-task study of laterality, sex differences and handedness. Cortex 1991;27:105–9.
[2] Beckett PA. Similar processing of real- and subjective-contour Poggendorff figures by men and women. Perceptual and Motor Skills 1990;70:51–6.
[3] Bertelson J, Morais J. A Ponzo-like illusion left and right of fixation: a failed prediction. Neuropsychologia 1983;21:105–9.
[4] Boucher R, Bryden MP. Laterality effects in the processing of melody and timbre. Neuropsychologia 1997;35:1467–73.
[5] Bryden MP. Measuring handedness with questionaires. Neuropsychologia 1977;15:617–24.
[6] Bryden M. Evidence for sex differences in cerebral organisation. In: Wittig M, Peterson A, editors. Determinants of sex-related differences in cognitive functioning. NY: Academic Press, 1979. p. 121–43.
[7] Chiarello C, McMahon MA, Schaefer K. Visual cerebral lateralization over phases of the menstrual cycle: a preliminary investigation. Brain and Cognition 1989;11:18–36.
[8] Clem RK, Pollack RH. Illusion magnitude as a function of visual field exposure. Perception and Psychophysics 1975;17(5):450–4.
[9] Corballis MC, Sidey S. Effects of concurrent memory load on visual-field differences in mental rotation. Neuropsychologia 1993;31:183–97.
[10] Fox R. Visual masking. In: Held R, Leibowitz HW, Teuber HL, editors. Perception. Handbook of Sensory Physiology VIII. Berlin: Springer–Verlag, 1978. p. 629–53.
[11] Gillam B. Geometrical illusions. Scientific American 1980;242:86–95.
[12] Grabowska A, Szymanska O, Nowicka A, Kwiecien M. The effect of unilateral lesions on perception of visual illusions. Behavioural Brain Res 1992;47:191–7.
[13] Gregory RL. Eye and Brain, The Psychology of Seeing, 5th Edition. Oxford: Oxford University Press, 1998.
[14] Greist SM, Grier JB. The effect of retinal location on the magnitude of the Poggendorff illusion. Perception and Psychophysics 1977;21:249–52.
[15] Halpern DF. Sex differences in cognitive abilities. Hilsdale: Lawrence Erlbaum Associates, 1986.
[16] Halpern DF. Sex, brains, hands, and spatial cognition. Developmental Review 1996;16:261–70.
[17] Hausmann M., Behrendt-Körbitz S., Kautz H., Lamm C., Radelt F., Güntürkün O. Sex differences in oral asymmetries during word repetition. Neurosychologia 1998;36:1397–402.
[18] Hess RF, Dakin SC. Absence of contour linking in peripheral vision. Nature 1997;390:602–4.
[19] Holland M, Wilson AE, Goddard M. Lack of sex differences with the Baldwin illusion. Perceptual and Motor Skills 1990;71:305–6.
[20] Holmes S. The effects of ocular dominance and cerebral specialization on the magnitude of the Mueller–Lyer. Doctoral dissertation, University of Georgia 1974.
[21] Hough MS, Daniel HJ, Snow MA, O'Brien KF, Hume WG. Gender differences in laterality patterens for speaking and singing. Neuropsychologia 1994;32:1067–78.
[22] Houlard N, Fraisse P, Hecaen H. Effects of unilateral hemispheric lesions on two types of optico-geometric illusions. Cortex 1976;12(3):232–40.
[23] Hyde JS. How large are cognitive gender differences? American Psychologist 1981;36:892–901.
[24] Inglis J, Lawson JS. Sex differences in the effects of unilateral brain damage on intelligence. Science 1981;212:693–5.
[25] Inglis J, Ruckman M, Lawson JS, MacLean AW, Monga TN. Sex differences in the cognitive effects of unilateral brain damage. Cortex 1982;18:257–76.
[26] Juarez J, Corsi-Cabrera M. Sex differences in intrahemispheric correlation and spectral power of EEG activity. Brain Research Bulletin 1995;38:149–51.
[27] Kimura D. The asymmetry of the human brain. Scientific American 1970;228:70–8.
[28] Kimura D, Harshmann RA. Sex differences in brain organization for verbal and non-verbal functions. In: De Vries GJ, De

Bruin JPC, Uylings HBM, Corner MA, editors. Sex Differences in the Brain, Progress in Brain Research, , vol. 61. Amsterdam: Elsevier, 1984. p. 423–39.

[29] Marzi CA, Smania N, Martini MC, Gambina G, Tomelleri G, Palamara A. Implicit redundant-targets effect in visual extinction. Neuropsychologia 1996;34:9–22.

[30] McGee MG. Human spatial abilities: psycholetric studies and environmental, genetic, hormonal, and neurological influences. Psychological Bulletin 1979;86:889–918.

[31] McGlone J. Sex differences in the cerebral organization of verbal functions in patients with unilateral brain lesions. Brain 1977;100:775–93.

[32] McGlone J. Sex differences in functional brain asymmetry. Cortex 1978;14:122–8.

[33] McGlone J. Sex differences in human brain asymmetry: a critical survey. Behavioral and Brain Sciences 1980;3:215–63.

[34] McGlone J, Kertesz A. Sex differences in cerebral processing of visuospatial tasks. Cortex 1973;9:313–20.

[35] McKeever VF. Hormone and hemisphericity hypothesis regarding cognitive sex differences: possible future explanatory power, but current empirical chaos. Learning and Individual Differences 1995;7:323–40.

[36] Miller J. Divided attention: evidence for coactivation with redundant signals. Cognitive Psychology 1982;14:247–79.

[37] Mordkoff JT, Miller J, Roch A-C. Absence of coactivation in the motor component: evidence of pschophysiological measures of target detection. Journal of Experimental Psychology and Human Perception and Performance 1996;22:25–41.

[38] Nobre AC, Sebestyen GN, Gitelman DR, Mesulam MM, Frackowiak RSJ, Frith CD. Functional localization of the system for visuospatial attention using positron emission tomography. Brain 1997;120(3):515–33.

[39] Oldfield RC. The assessment and analysis of handedness: The Edinburgh Inventory. Neoropsychologia 1971;9:97–113.

[40] Phippard D. Hemifield differences in visual perception in deaf and hearing subjects. Neuropsychologia 1977;15:555–61.

[41] Polich JM. Hemispheric differences in stimulus identification. Perception and Psychophysics 1978;24:49–57.

[42] Porac C, Coren S, Girgus JS, Verde M. Visual-geometric illusions: unisex phenomena. Perception 1979;8:401–12.

[43] Potter SM, Graves RE. Is interhemispheric transfer related to handedness and gender? Neuropsychologia 1988;26:319–25.

[44] Pratarelli ME, Steitz BJ. Effects of gender on perception of spatial illusions. Perceptual and Motor Skills 1995;80:625–6.

[45] Pressey AW, Wilson AE. Another look at age changes in geometric illusions. Bulletin of the Psychonomic Society 1978;12:333–6.

[46] Raab D. Statistical facilitation of simple reaction time. Transactions of the New York Academy of Sciences 1962;43:574–90.

[47] Rothwell B, Zaidel E. Visual field differences in the magnitude of the Opel–Kundt illusion vary with processing time. Perception and Psychophysics 1990;47:180–90.

[48] Sasanuma S, Kobayashi Y. Tachistoscopic recognition of line orientation. Neuropsychologia 1978;16:239–42.

[49] Sergent J. Role of the input in visual hemispheric asymmetries. Psychological Bulletin 1983;93(3):481–512.

[50] Shaywitz BA, Shaywitz SE, Pugh KR, Constable RT, Skudlarski P, Fulbright RK, Bronen RA, Fletcher JM, Shankweiler DP, Katz K, Gore JC. Sex differences in the functional organization of the brain for language. Nature 1995;373:607–9.

[51] Umilta D, Rizzolatti G, Marzi CA, Zamboni G, Franzini C, Camarda R, Berlucchi G. Hemispheric differences in the discrimination of line orientation. Neuropsychologia 1974;12:165–74.

[52] Usher M, Donnelly N. Visual synchrony affects binding and segmentation in perception. Nature 1998;394:179–82.

[53] Voyer D. On the magnitude of laterality effects and sex differences in functional lateralities. Laterality 1996;1:51–83.

[54] Voyer D, Voyer S, Bryden MP. Magnitude of sex differences in spatial abilities: a meta-analysis and consideration of critical variables. Psychological Bulletin 1995;117:250–70.

[55] Waber DP. Maturation: thoughts on renewing an old acquaintanceship. In: Caplan D, editor. Biological studies of Mental Processes. MIT Press, 1982. p. 8–26.

[56] Witkin HA, Dyk RB, Faterson HF, Goodenough DR, Karps SA. Psychological Differentiation. NY: Wiley, 1962.